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EFFECTS OF WING-TIP FIN AND NOSE GEOMETRY ON THE STABILITY CHARACTERISTICS OF A TOW TARGET CONFIGURATION AT MACH NUMBERS FROM 0.5 TO 0.9

H. Kaupp

ARO, Inc.

November 1971

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NOTICES

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H. Kaupp
ARO, Inc.

FOREWORD

The work reported herein was sponsored by the Air Force Armament Laboratory (AFATL/DLIV/Lt J. M. Walz), Armament Development and Test Center, Air Force Systems Command (AFSC). under Program Element 62204F, Project 7848, Task 09.

The test results presented were obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates. Inc.), contract operator of the Arnold Engineering Development Center (AEDC), AFSC, Arnold Air Force Station, Tennessee, under Contract F40600-72-C-0003. The test was conducted on August 17 and 18, 1971, under ARO Project No. PC0134. The manuscript was submitted for publication on October 8, 1971.

This technical report has been reviewed and is approved.

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ABSTRACT

Aerodynamic stability and drag coefficients were obtained for five configurations of a 0.166-scale tow target at Mach numbers from 0.5 to 0.90. The primary configuration variables were tip fin size and fin cant angle. Effects of a blunted ogive nose as compared to an inlet shape nose were also investigated.

CONTENTS

APPENDIX
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NOMENCLATURE

Model forces and moments are oriented to a wind axis system.

b Wing span, 0.717 ft

C_c Crosswind coefficient, crosswind force/$q_\infty S$

C_{c_β} Crosswind-force parameter measured at $\beta = 0$, $\partial C_c/\partial\beta$, per degree

C_D Drag coefficient, drag/$q_\infty S$

C_{D_o} Zero-lift drag coefficient, drag/$q_\infty S$

C_L Lift coefficient, lift/$q_\infty S$

C_{L_α} Lift-curve parameter measured at $\alpha = 0$, $\partial C_L/\partial\alpha$, per degree

C_ℓ Rolling-moment coefficient, rolling moment/$q_\infty Sb$

C_{ℓ_β} Effective dihedral parameter measured at $\beta = 0$, $\partial C_\ell/\partial\beta$, per degree

C_m Pitching-moment coefficient, pitching moment/$q_\infty S\bar{c}$ (see Fig. 1e for moment reference location)

C_{m_α} Longitudinal stability parameter measured at $\alpha = 0$, $\partial C_m/\partial\alpha$, per degree

C_n Yawing-moment coefficient, yawing moment/$q_\infty Sb$

C_{n_β} Directional stability parameter measured at $\beta = 0$, $\partial C_n/\partial\beta$, per degree

$C_{P,b}$ Base pressure coefficient, $(P_b - P_\infty)/q_\infty$

$\bar{c}$ Mean aerodynamic chord, 0.584 ft.

M_∞ Free-stream Mach number

P_b Base pressure, psfa

P_∞ Free-stream static pressure, psfa

q_∞ Free-stream dynamic pressure, psf

S Wing area, 0.414 sq ft

α Angle of attack, deg

β Angle of sideslip, deg

Note: C_D, C_{D_o}, C_L, and C_c have been adjusted to correspond to conditions of free-stream pressure acting at the model base.

SECTION I
INTRODUCTION

Wind tunnel tests were conducted in the Propulsion Wind Tunnel Facility (PWT), Aerodynamic Wind Tunnel (4T) to determine the stability and drag contribution of two wing-tip fin configurations to a tow target model. The smaller of the two fin configurations was tested at cant angles of 0 and 45 deg. whereas the larger fin was tested at a cant angle of 45 deg only. The primary objective of the test was to determine which of the two fin configurations would aerodynamically stabilize the model with a minimum increase in model drag.

The stability and drag characteristics of the model with an inlet shaped nose as opposed to a blunted ogive nose were also investigated.

The test was conducted over the Mach number range from 0.50 to 0.90 and angles of attack from -2 to 10 deg. Sideslip angle was varied from -2 to 6 deg at 0- and 5-deg angle of attack.

SECTION II
APPARATUS

2.1 TEST FACILITY

Tunnel 4T is a closed-loop, continuous flow, variable density tunnel in which the Mach number can be varied from 0.1 to 1.3. At all Mach numbers, the stagnation pressure can be varied from 300 to 3700 psfa. The test section is 4 ft square and 12.5 ft long with perforated. variable porosity (0.5- to 10-percent-open) walls. It is completely enclosed in a plenum chamber from which the air can be evacuated, allowing part of the tunnel airflow to be removed through the perforated walls of the test section. A more thorough description of the tunnel may be found in the Test Facilities Handbook.[1]

2.2 TEST ARTICLES

Photographs and details of the 0.166-scale model are shown in Figs. 1a through g (Appendix). The basic model (N1B) consisted of a semicylindrical fuselage with a blunted ogive nose and boattail, a 1.24 aspect ratio wing having a leading-edge sweep of 32 deg and two wing-tip pods. Model nose geometry changes were made by adding an inlet nose (N2) to the model. The two model noses are shown in Fig. 1g. No provision was made to allow air captured by the inlet to pass through the model. The three wing-tip fin configurations were mounted to the wing-tip pods. Each fin consisted of an upper and lower half mounted symmetrically about the wing chord. Fins F1 and F2 were mounted at 45 deg from the vertical, and fin F3 was mounted in a vertical position. Fins F2 and F3 were similar in planform area and were approximately 26 percent of the wing area (area of one complete fin). Fin F1 was approximately 36 percent of the wing area. Wing planform area was 0.414 sq ft (wing area between pod centerlines).

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[1] Test Facilities Handbook (Ninth Edition). "Propulsion Wind Tunnel Facility, Vol. 4." Arnold Engineering Development Center, July 1971.

2.3 INSTRUMENTATION

A six-component, internal strain-gage balance was used to measure the aerodynamic forces and moments acting on the model. The electrical output for each balance component was measured by a bridge circuit and an analog-to-digital converter. Model base pressures were measured at two positions in the plane of the model base. The magnitude of the pressures was determined by strain-gage pressure transducers. Outputs of the transducers were converted to digital form and averaged before use in computation of the base-drag force.

SECTION III
TEST DESCRIPTION

3.1 TEST CONDITIONS AND PROCEDURES

Aerodynamic forces and moments were measured at angles of attack from -2 to 10 deg and angles of sideslip from -2 to 6 deg while Mach number was held constant. A limited amount of data was obtained for the model in sideslip at a constant angle of attack of approximately 5 deg. These angle combinations were obtained by positioning the model in both pitch and roll. The tests were conducted at Mach numbers 0.50, 0.70, 0.80, and 0.90 at a nominal tunnel stagnation pressure of 3000 psfa. Tunnel stagnation temperature was varied from 120 to 130°F.

3.2 CORRECTIONS AND PRECISION OF MEASUREMENT

Model angle of attack was corrected for deflections of the balance and sting attributed to aerodynamic loads. The model drag and lift force was adjusted to correspond to the condition of free-stream static pressure acting at the model base. Nominal values for the base pressure coefficient ($C_{P,b}$) at 0-deg angle of attack were 0.067, 0.082, 0.094, and 0.119 for Mach numbers 0.50, 0.70, 0.80, and 0.90, respectively.

An estimation of the maximum uncertainty of the data based on the repeatability and known precision of the measuring equipment is listed below as determined for a confidence level of 95 percent:

ΔC_L	ΔC_D	ΔC_m	ΔC_Y	ΔC_n	ΔC_ℓ
±0.036	±0.005	±0.010	±0.003	±0.002	±0.003

The uncertainty in setting and maintaining Mach number is not greater than ±0.005. The Mach number variation in the portion of the tunnel occupied by the model is no greater than ±0.005. The uncertainty in angle of attack as corrected for sting deflection is ±0.1 deg.

SECTION IV
RESULTS AND DISCUSSION

Data showing the effects of adding wing-tip fins to the basic configuration (N1B) are presented in Figs. 2 through 4. The influence of the inlet nose (N2) on the aerodynamic characteristics of the model with wing-tip fins F1 is shown in Figs. 5 and 6. The data are summarized in terms of C_{L_α}, C_{D_0}, C_{m_α}, C_{c_β}, C_{n_β}, and C_{ℓ_β} in Figs. 7 through 9.

The basic configuration (N1B) was found to be longitudinally statically stable through the Mach number range (see Fig. 7). Adding wing-tip fins to the model increased both the lift parameter, C_{L_α}, and the negative value for the stability parameter, C_{m_α}, at all Mach numbers. As would be expected, increasing the fin cant angle from 0 to 45 deg and increasing the fin size increased the magnitude of these parameters in the above order. Also, as would be expected, the zero-lift drag coefficient increased with fin size (Fig. 7). Adding the large fin (F1) to the model more than tripled the negative value of C_{m_α} for the fin-off configuration and increased the zero-lift drag (C_{D_0}) by about 18 percent at Mach number 0.5. At Mach number 0.9, the negative value of C_{m_α} increased by a factor of approximately 5, with C_{D_0} showing a 10-percent increase as shown in Fig. 7. The addition of fins to the basic configuration resulted in an increase in magnitude of the side-force parameter, C_{c_β}, with the small vertical fins (F3) and the large canted fins (F1) having about the same value over the Mach number range (Fig. 8).

Configuration N1B is shown to be directionally unstable (Fig. 8) at all Mach numbers. The addition of the small fins (F2 or F3) decreased the magnitude of the instability. The vertical fin (F3) resulted in a slightly stable or neutrally stable configuration. The addition of the large fin (F1) resulted in a directionally stable configuration.

At 0-deg angle of attack, the effective dihedral parameter (C_{ℓ_β}) for both the finned and unfinned configurations is zero (Fig. 8). At an angle of attack of approximately 5 deg, the finned configurations show a stable or positive dihedral effect ($-C_{\ell_\beta}$) with the canted fins generally having the larger value (Fig. 9). In addition, all finned configurations are directionally stable at $\alpha \approx 5$ deg (no data were taken for the unfinned configurations).

Adding the inlet nose to the model with large tip-fins (N2BF1) produced no significant adverse effects in the stability parameters, C_{m_α} and C_{L_α} (Figs. 7 and 8); however, the drag coefficient was significantly increased throughout the Mach number range when the large tip fins were used.

SECTION V
CONCLUSIONS

An investigation to determine the stability and drag of a tow target model with variations in wing-tip fin size, cant angle, and model nose geometry resulted in the following conclusions:

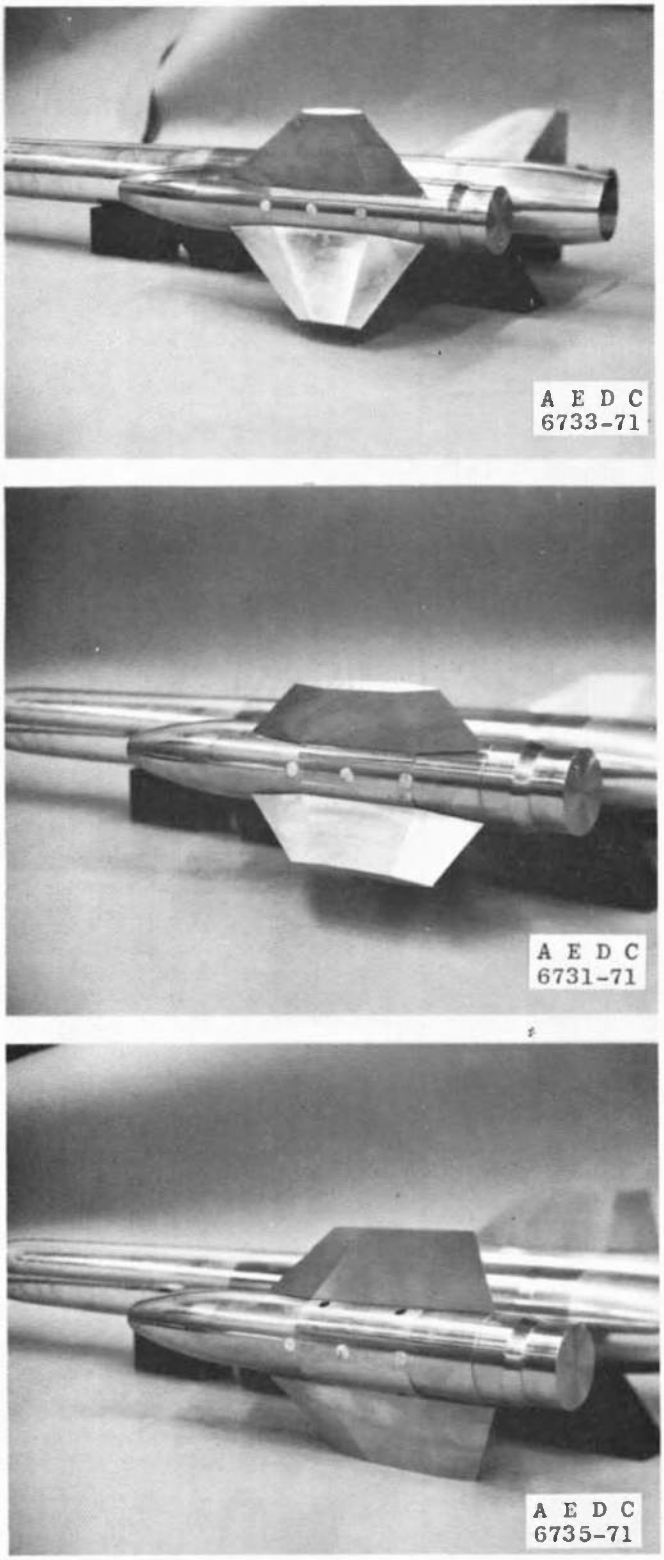
1. Adding wing-tip fins to the basic model (N1B) increased the longitudinal static stability of the model. An increase in cant angle from 0 to 45 deg and an increase in fin area increased the model stability, each increasing the magnitude of longitudinal stability parameter C_{m_α} in the above order.

2. Adding wing-tip fins (F2 or F3) decreased the directional instability of the basic model. The large fins (F1) were required to produce a directionally stable configuration throughout the Mach number range.

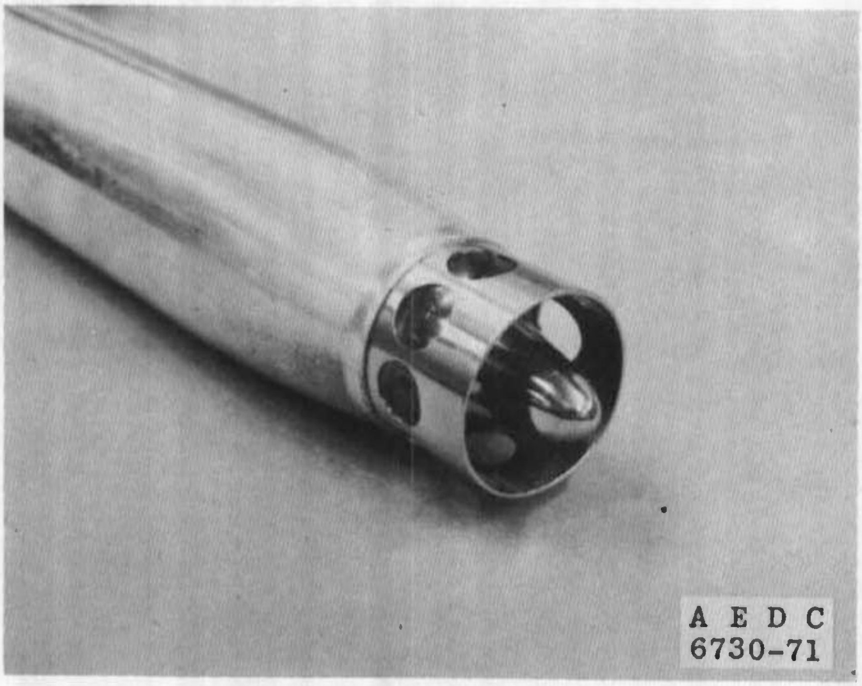
3. At an angle of attack of approximately 5 deg, the finned configurations exhibited a positive dihedral effect, whereas the dihedral effect was zero at 0-deg angle of attack.

4. Changing the model nose geometry from a blunted ogive shape to an inlet shape produced no adverse effects on the stability characteristics of the model.

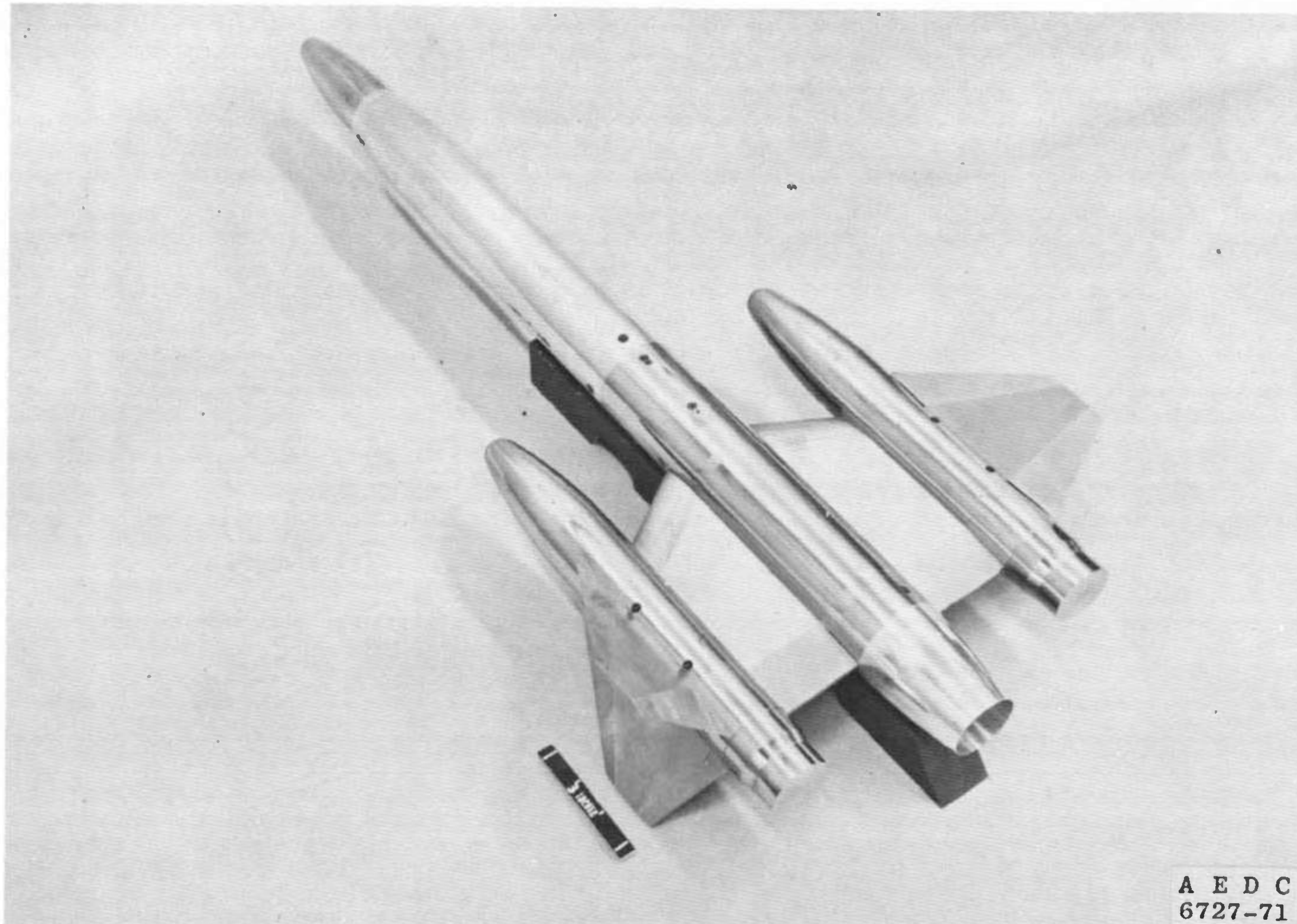
APPENDIX
ILLUSTRATIONS



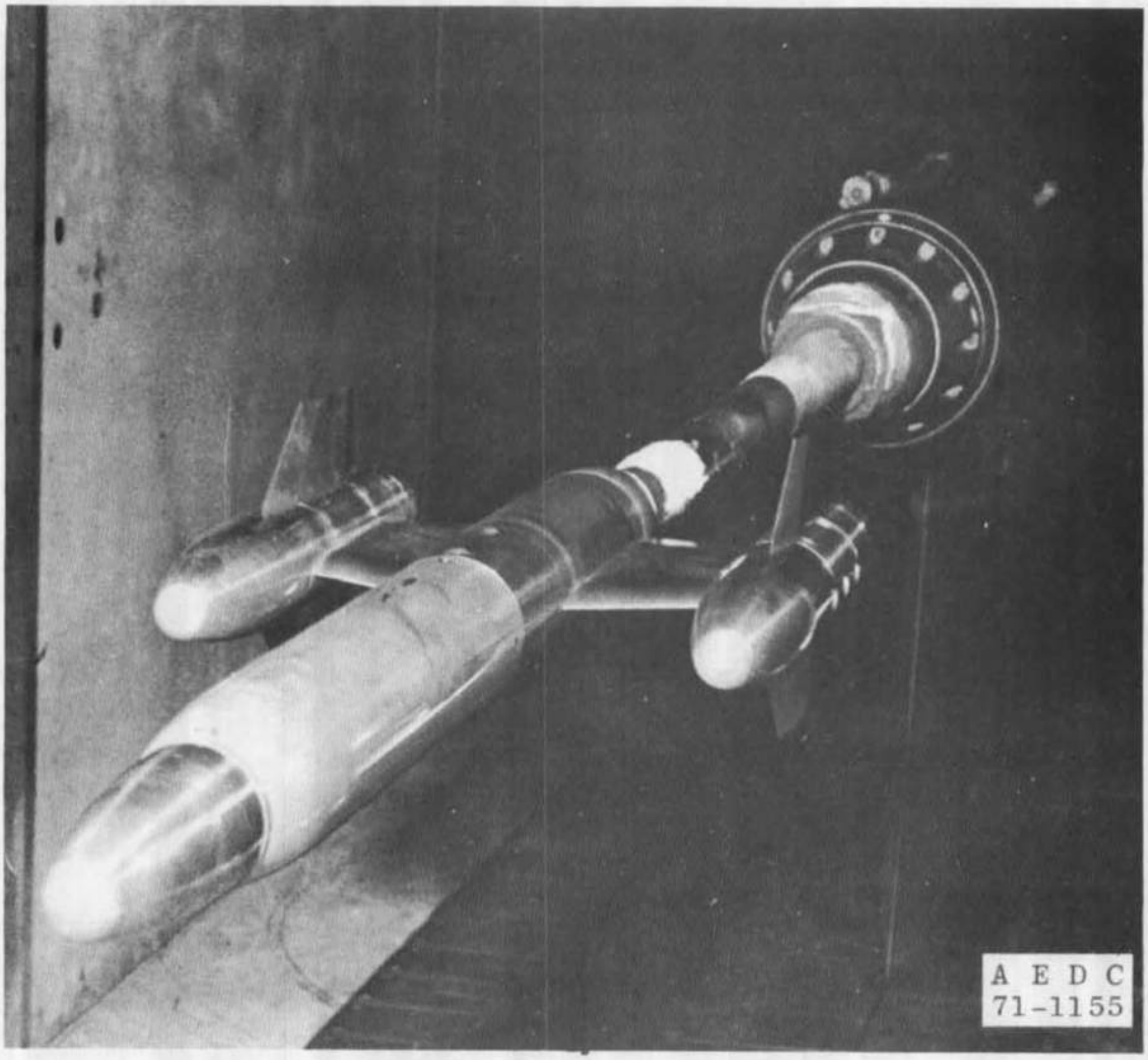
a. Model Photograph (Configuration N1BF1)
Fig. 1 Model Description



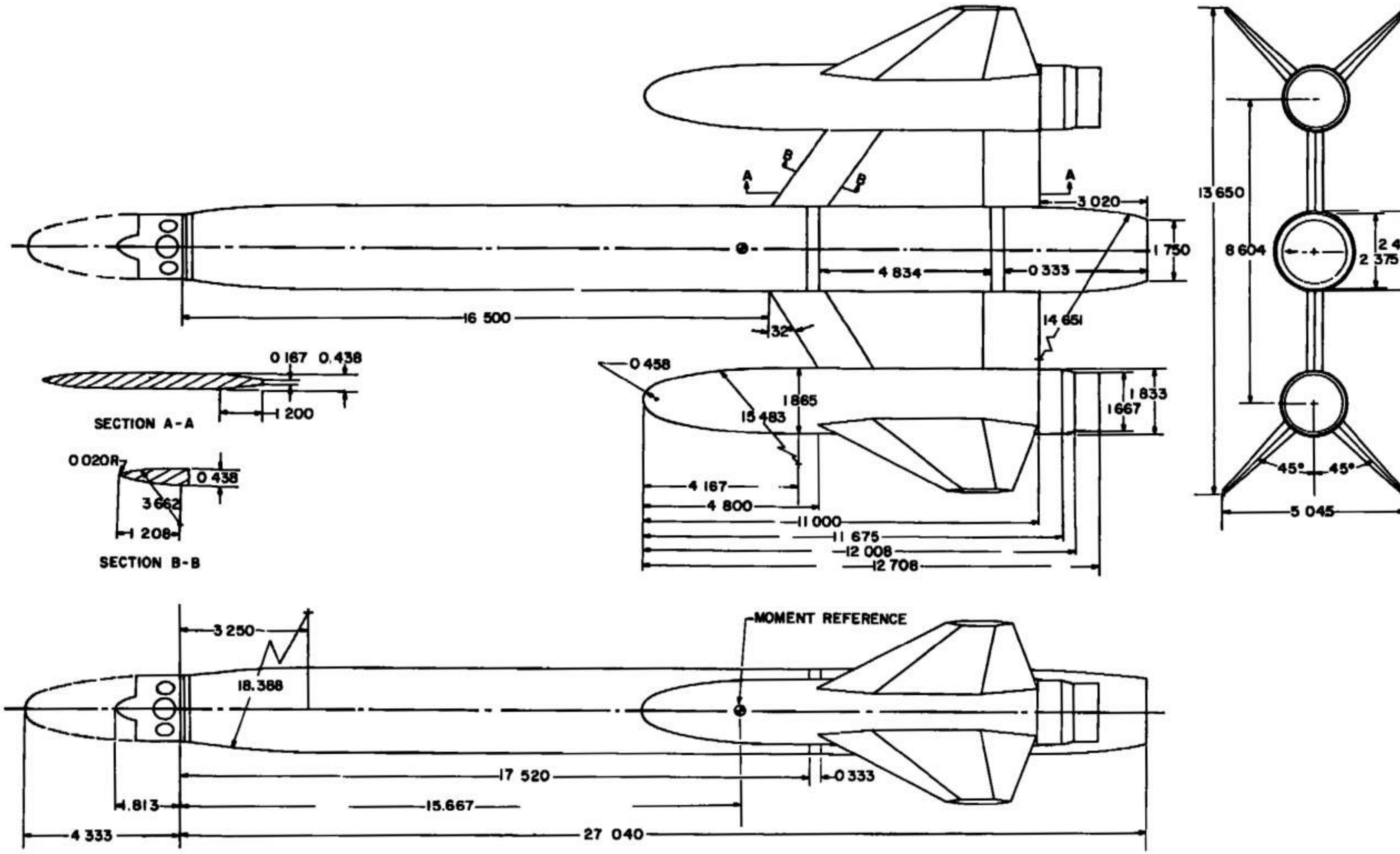
b. Photograph of Inlet Nose (Configuration N2)
Fig. 1 Continued



c. Photograph of Fins
Fig. 1 Continued



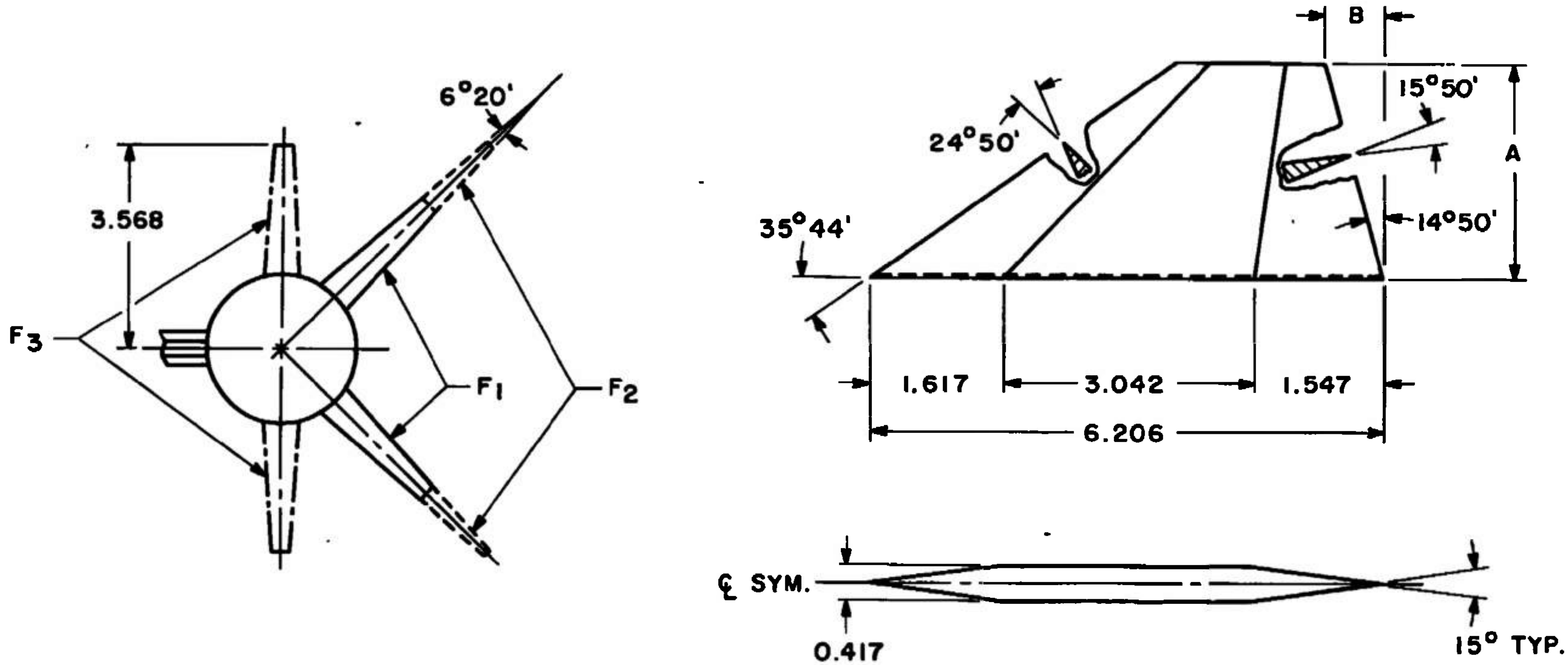
d. Photograph of Model in Wind Tunnel (Configuration N1BF3)
Fig. 1 Continued



ALL DIMENSIONS IN INCHES

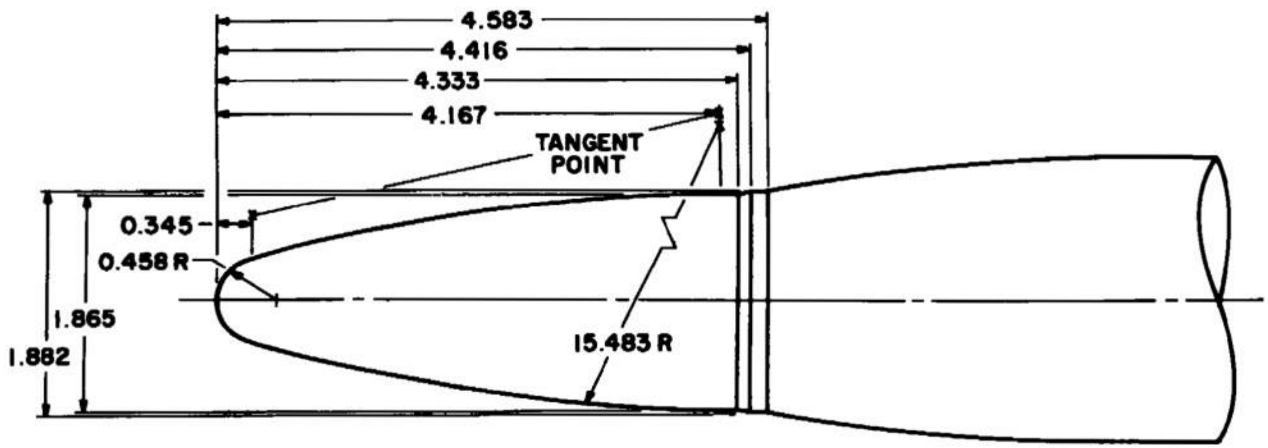
e. Model Details
Fig. 1 Continued

TAIL	A	B
F_1	2.659	0.704
F_2	1.614	0.427
F_3	1.614	0.427



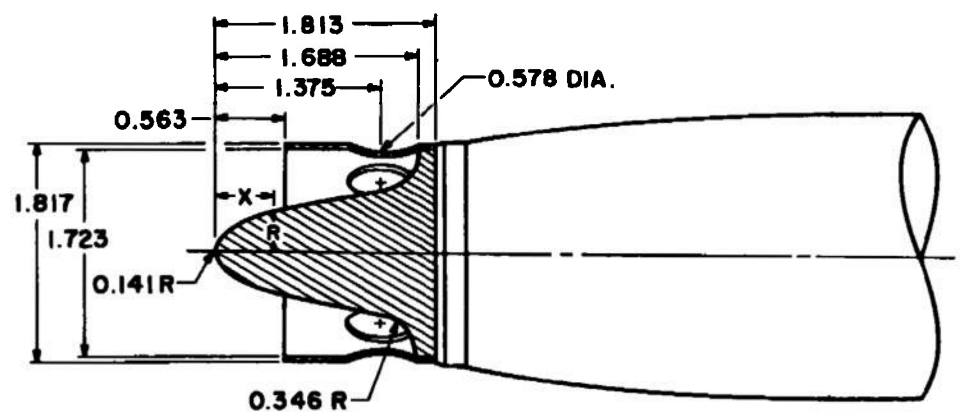
ALL DIMENSIONS IN INCHES

f. Fin Details
Fig. 1 Continued



N1

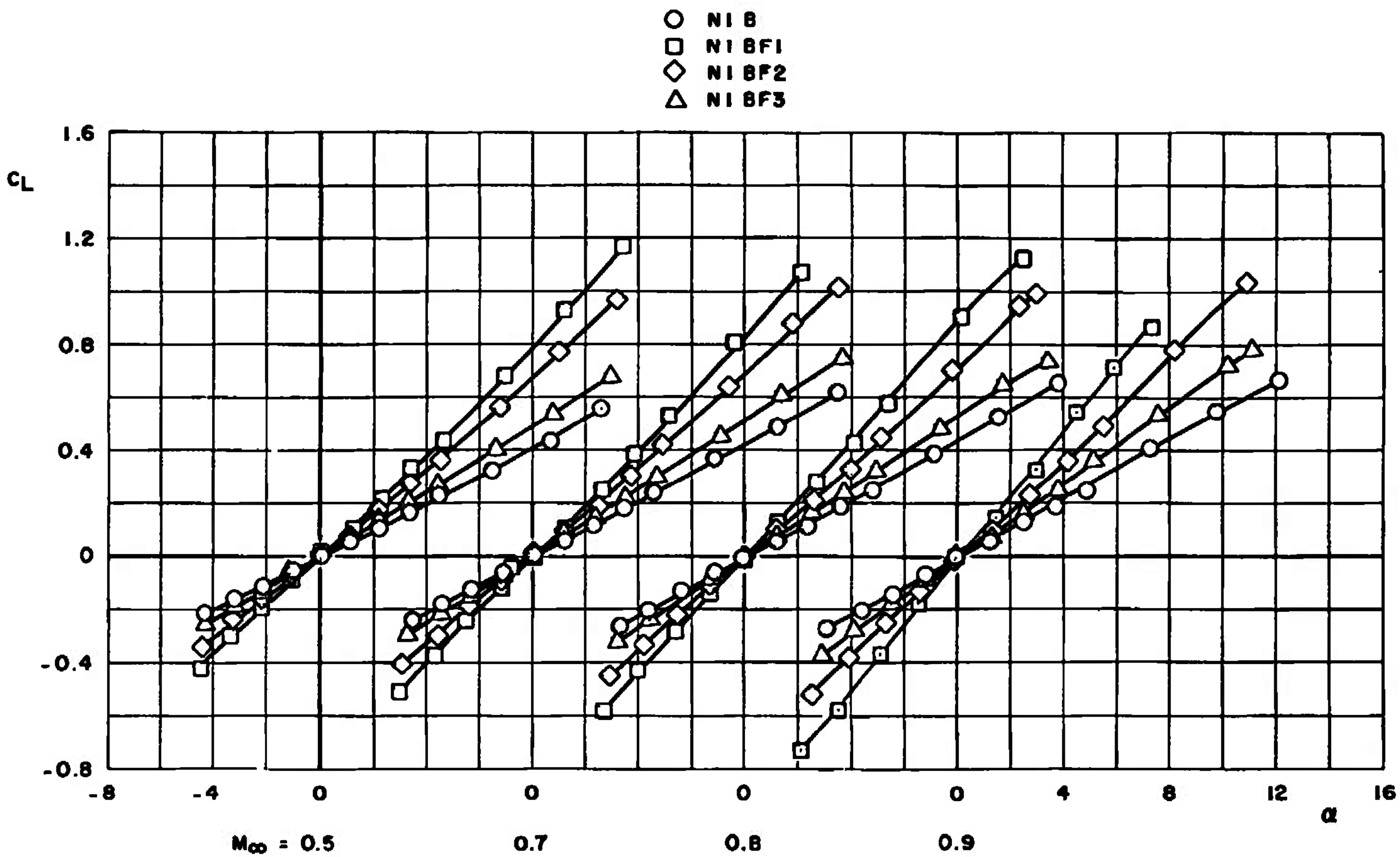
X	R
0.000	0.000
0.100	0.160
0.200	0.225
0.300	0.275
0.400	0.310
0.500	0.330
0.600	0.360
0.700	0.380
0.800	0.400
0.900	0.420
1.000	0.440
1.100	0.460
1.200	0.480
1.300	0.500
1.364	0.512



N2

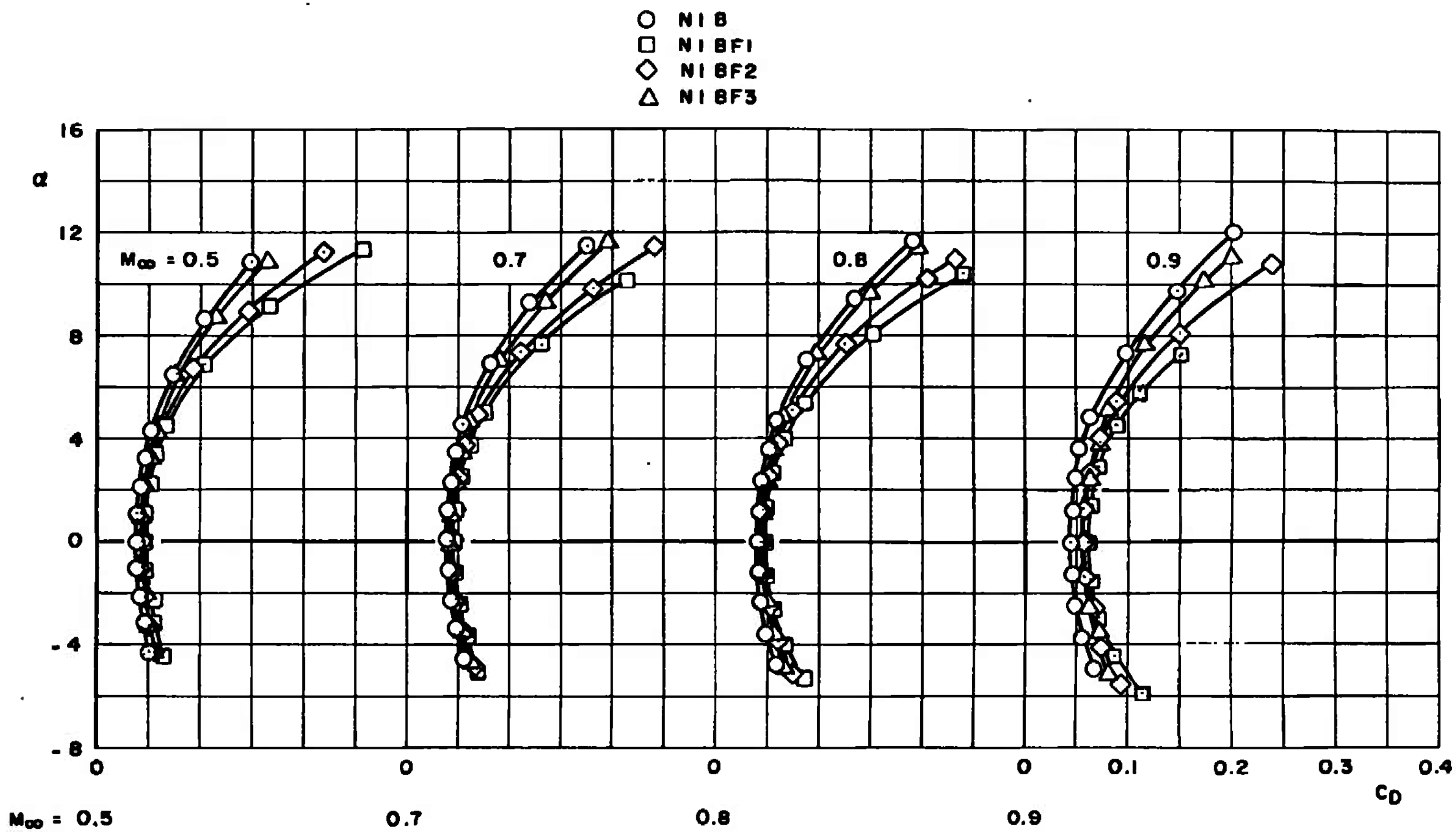
ALL DIMENSIONS IN INCHES

g. Nose Details
Fig. 1 Concluded

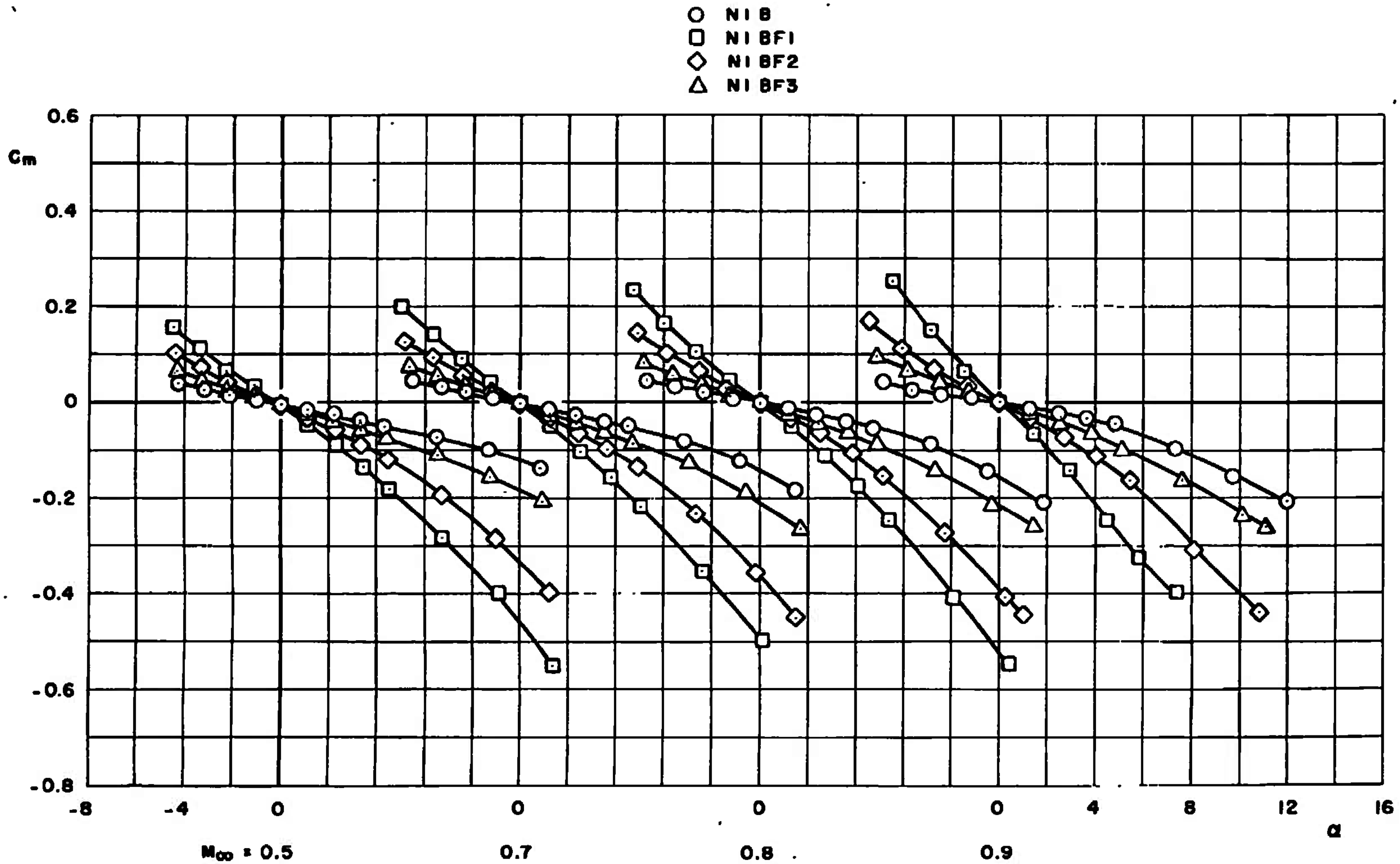


a. Variation of C_L with α

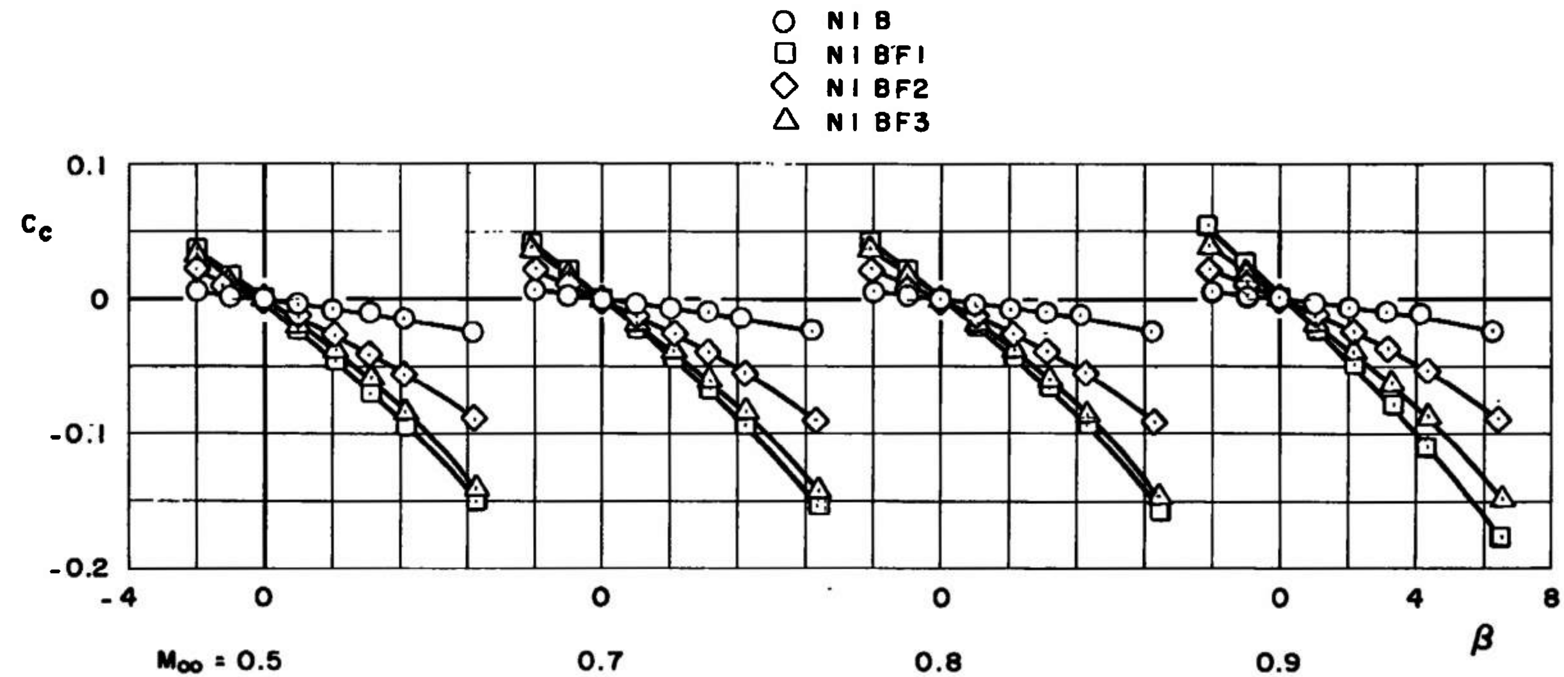
Fig. 2 Effect of Wing-Tip Fins on the Model Aerodynamic Characteristics in Pitch



b. Variation of C_D with α
Fig. 2 Continued

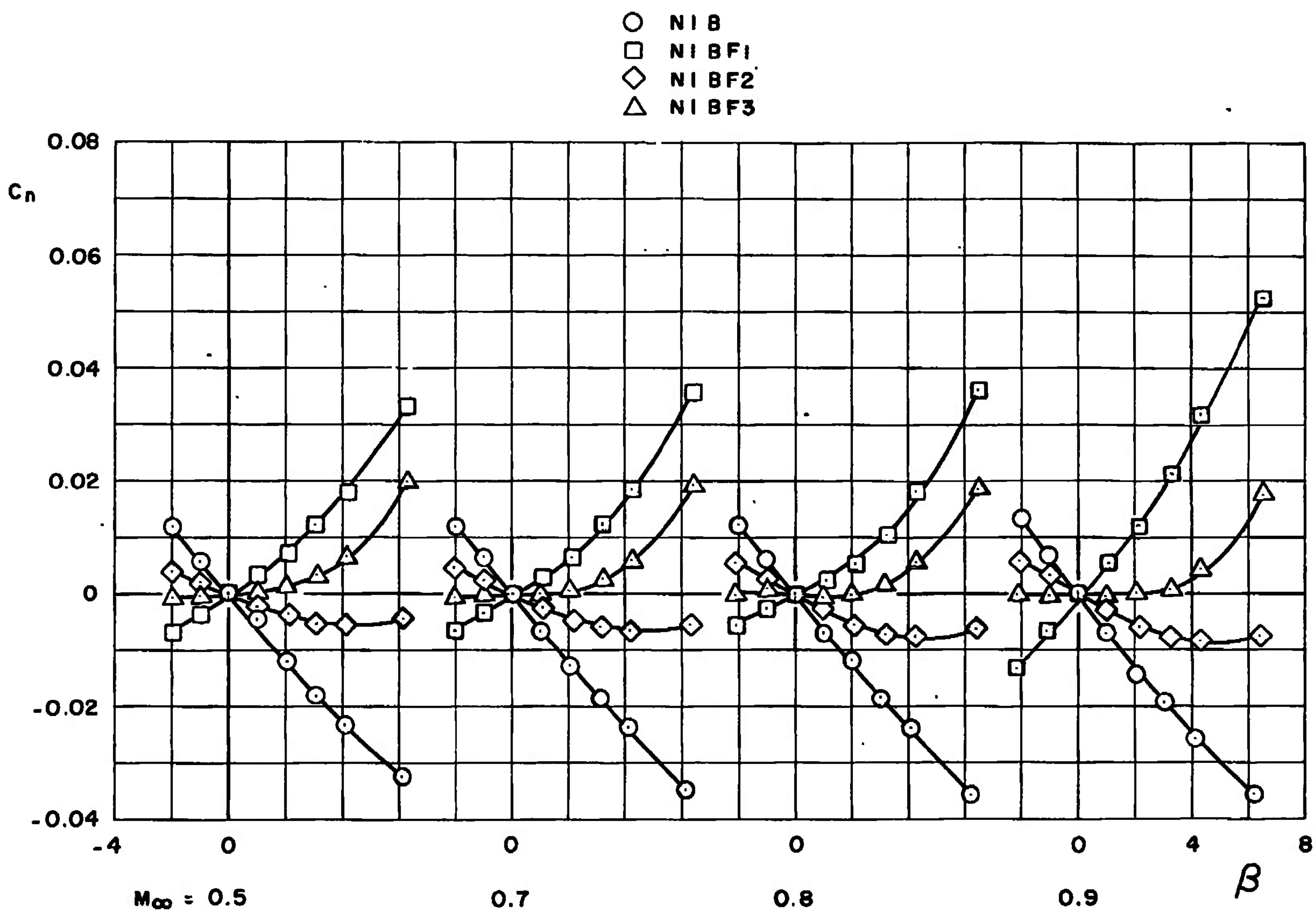


c. Variation of C_m with α
Fig. 2 Concluded

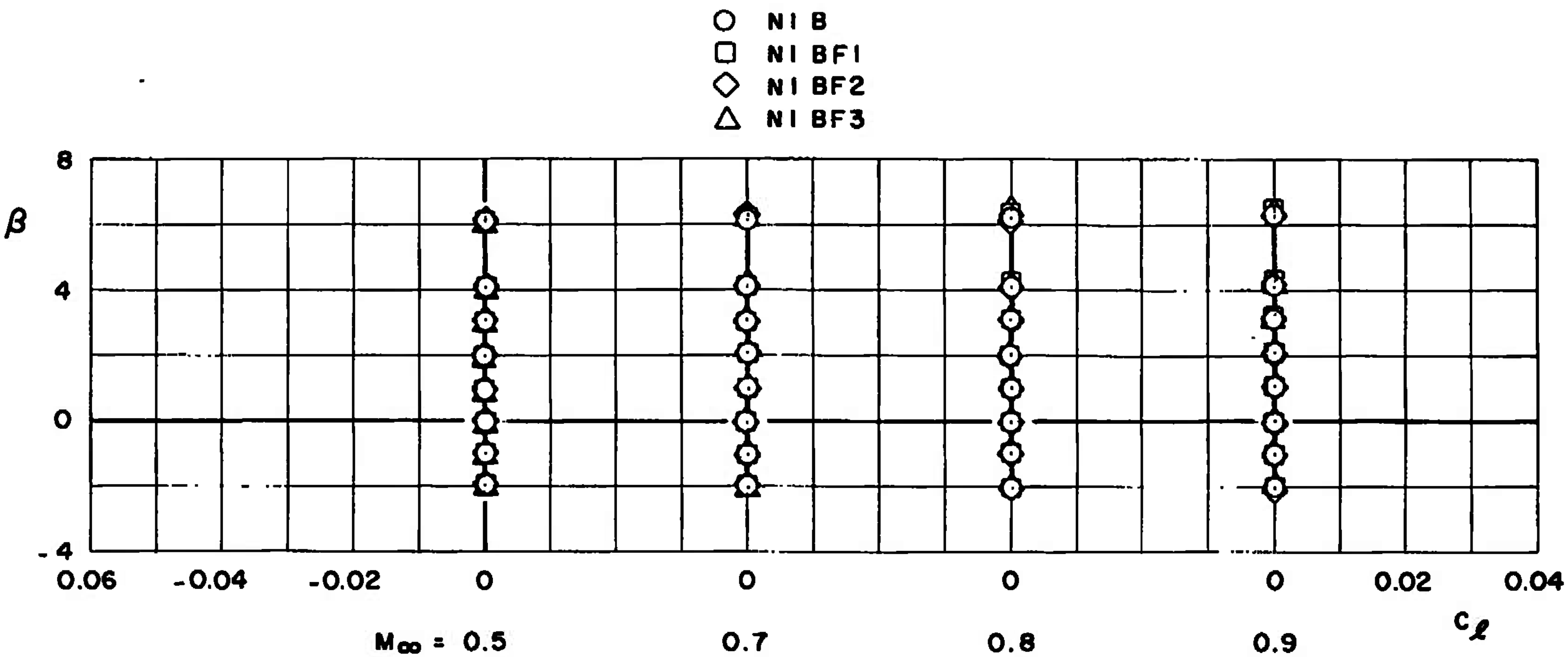


a. Variation of C_c with β

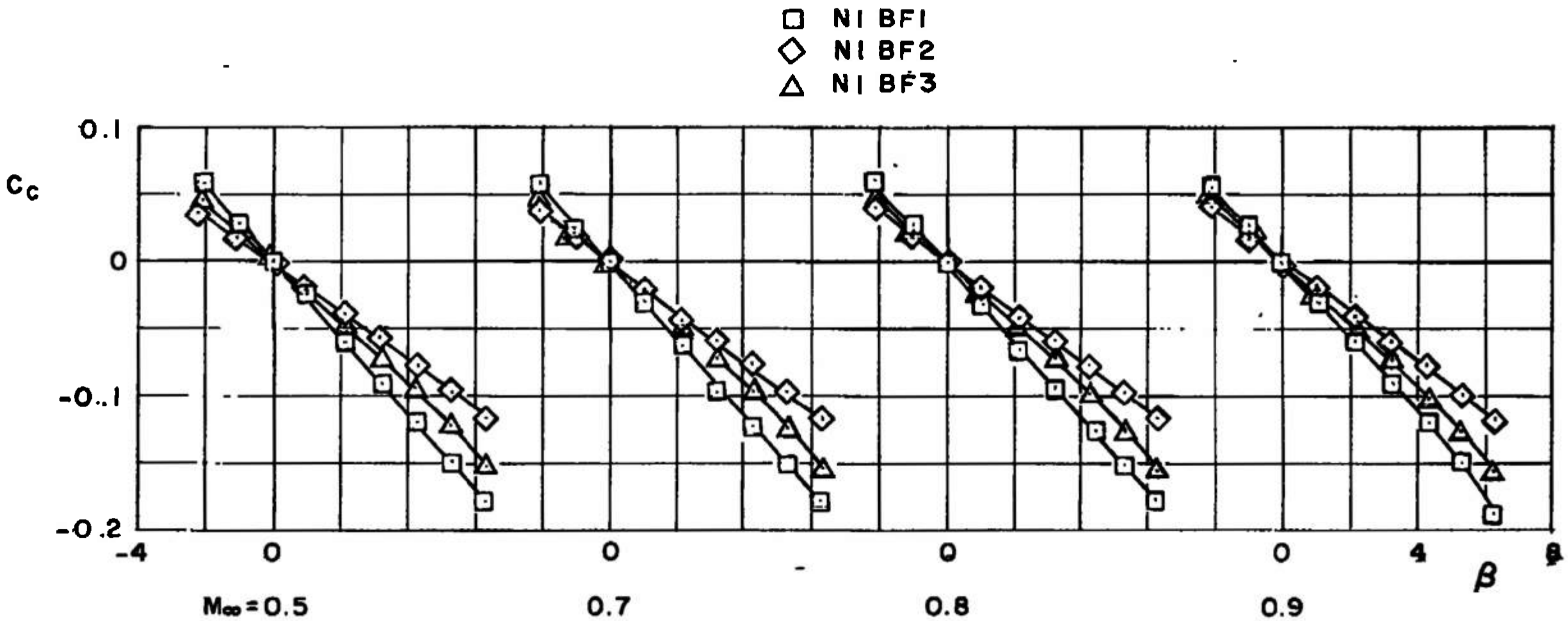
Fig. 3 Effect of Wing-Tip Fins on the Model Aerodynamic Characteristics in Sideslip (α = 0 deg)



b. Variation of C_n with β
Fig. 3 Continued

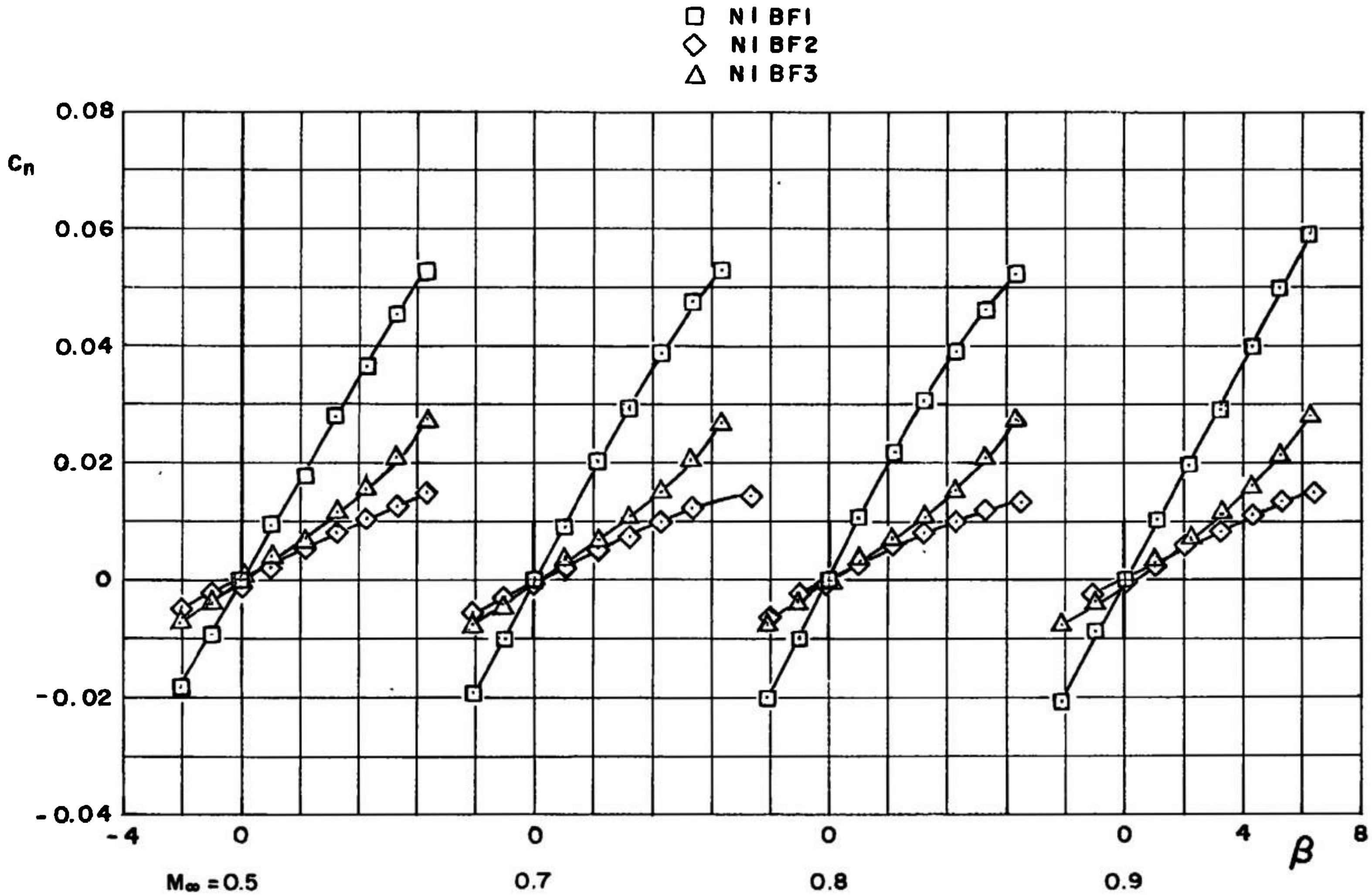


c. Variation of C_ℓ with β
Fig. 3 Concluded

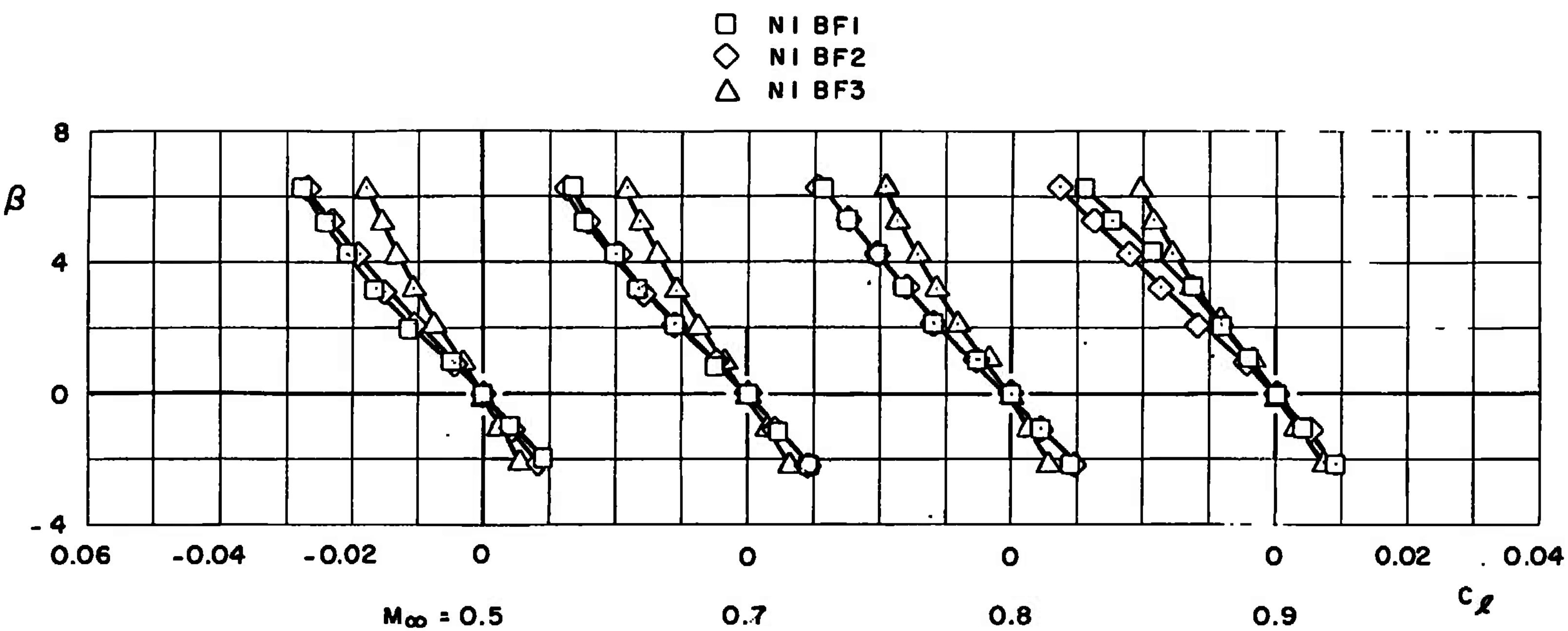


a. Variation of C_c with β

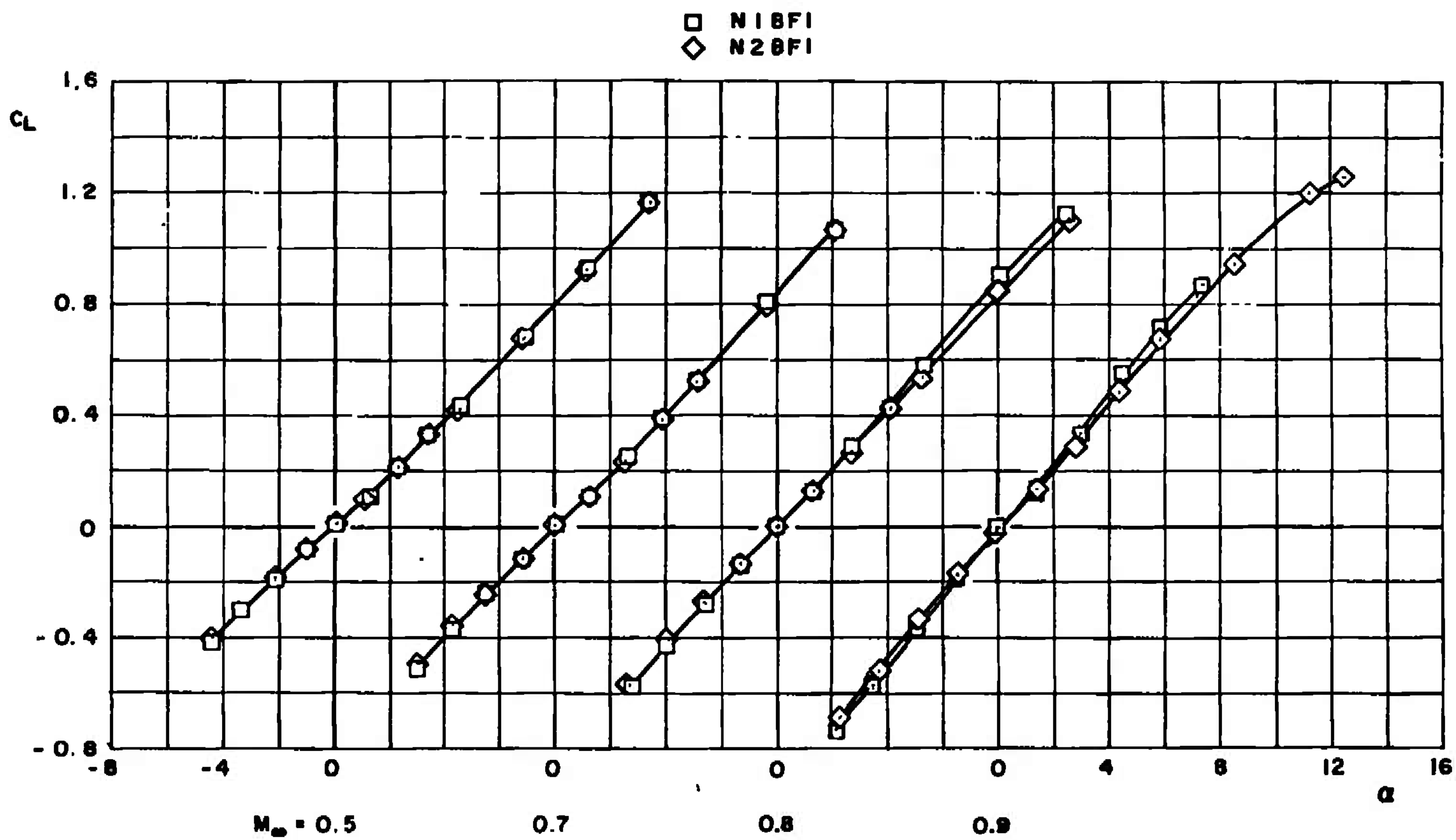
Fig. 4 Effect of Wing-Tip Fins on the Model Aerodynamic Characteristics in Sideslip ($\alpha \approx 5$ deg)



b. Variation of C_n with β
Fig. 4 Continued

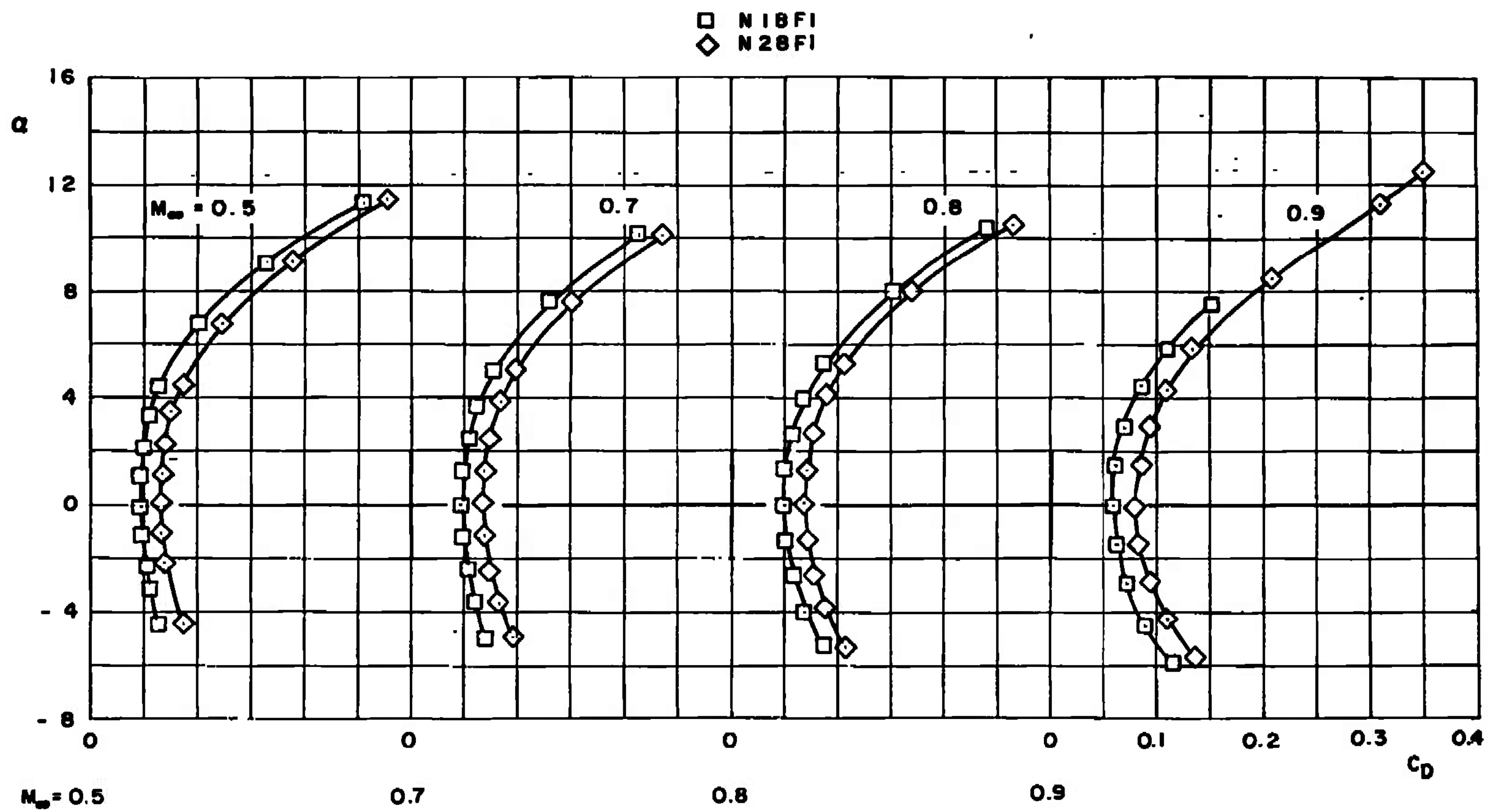


c. Variation of C_ℓ with β
Fig. 4 Concluded

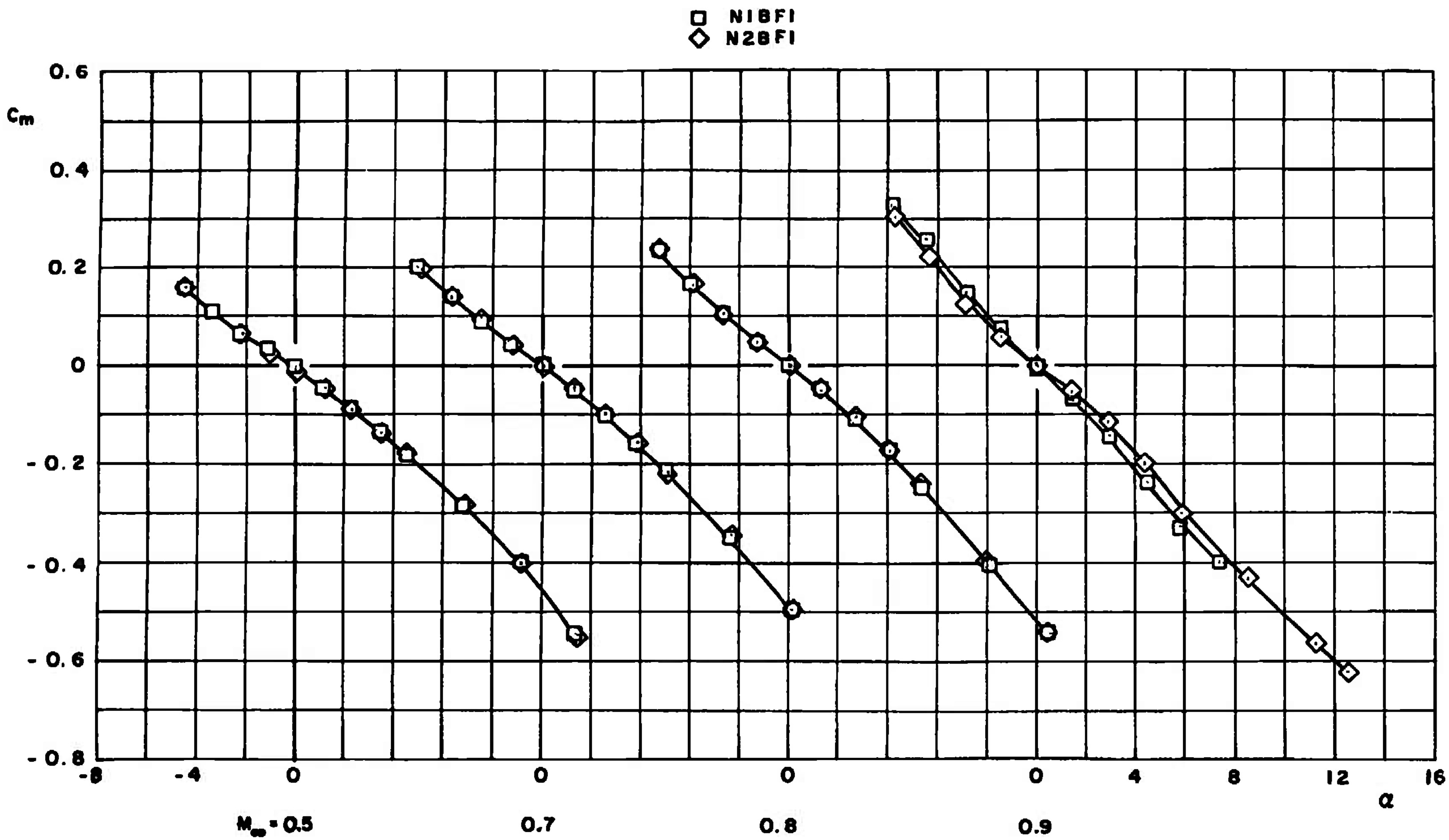


a. Variation of C_L with α

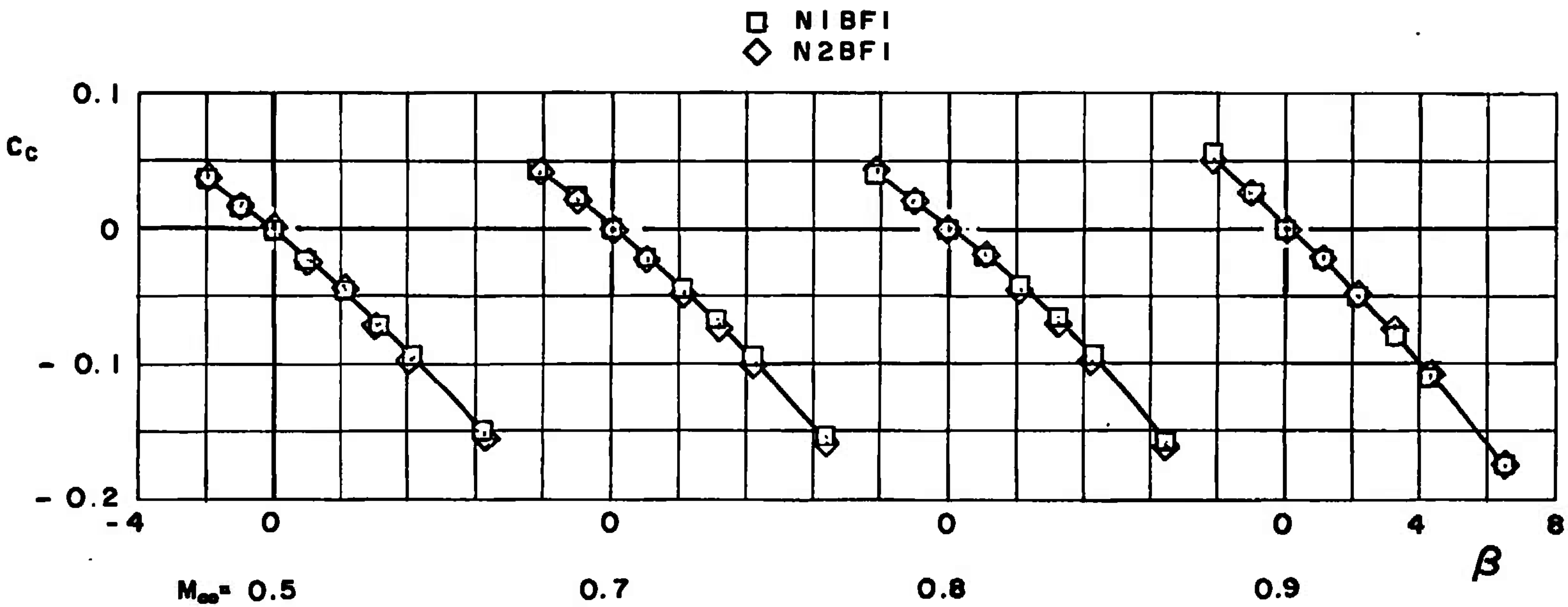
Fig. 5 Effect of Inlet Nose on the Aerodynamic Characteristics in Pitch



b. Variation of C_D with α
Fig. 5 Continued

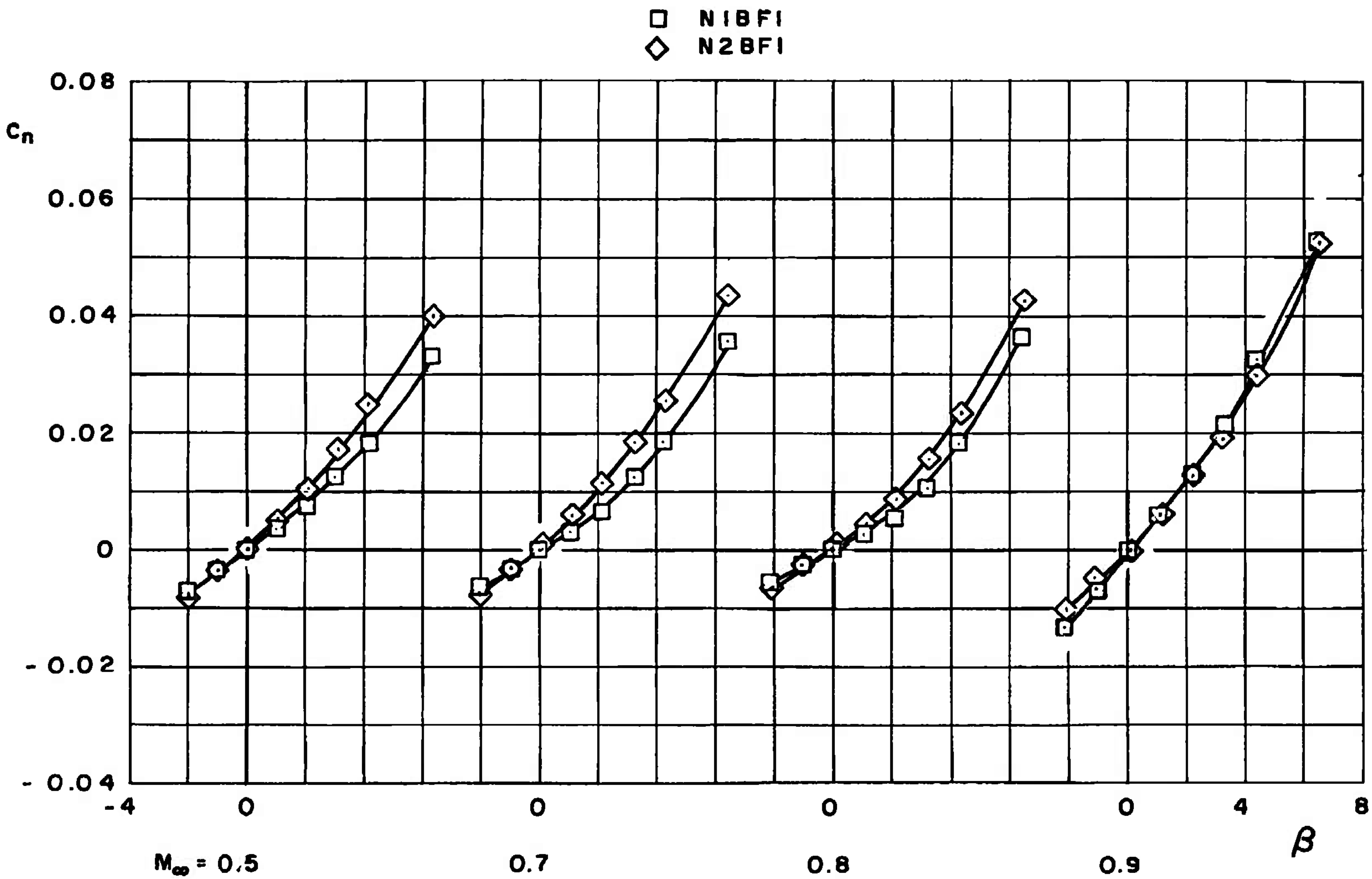


c. Variation of C_m with α
Fig. 5 Concluded

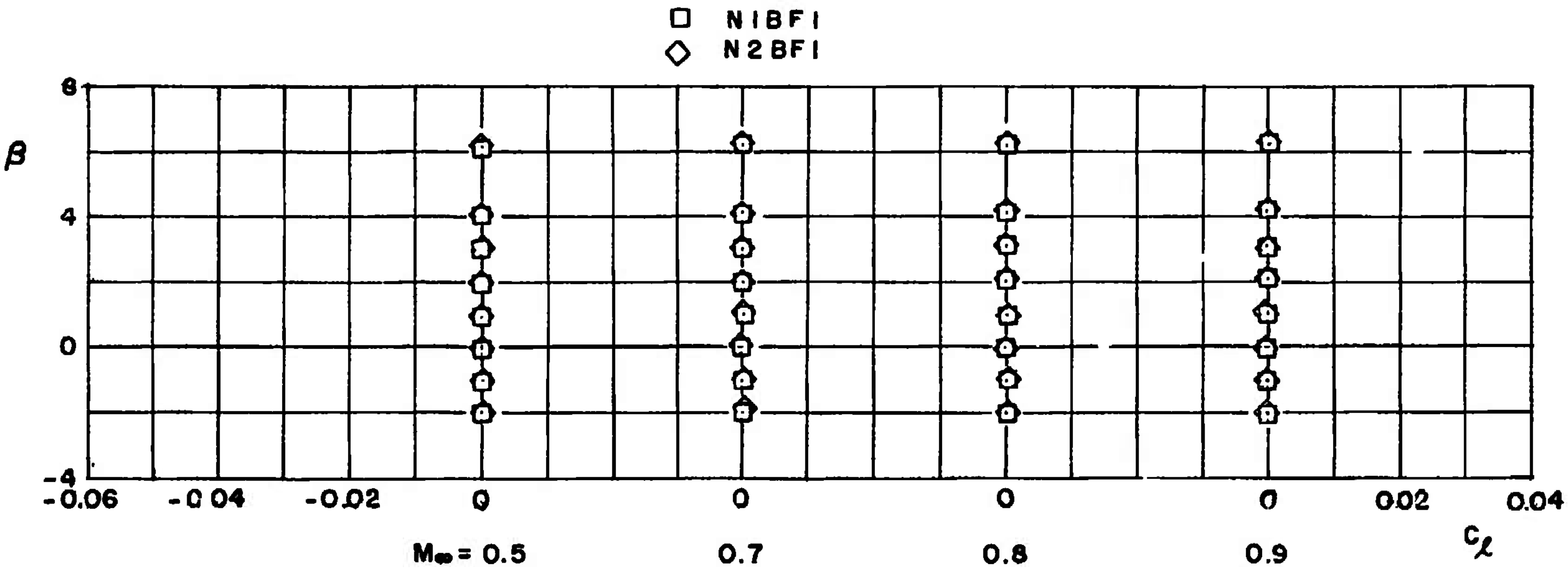


a. Variation of C_c with β

Fig. 6 Effect of Inlet Nose on the Aerodynamic Characteristics in Sideslip (α = 0 deg)



b. Variation of C_n with β
Fig. 6 Continued



c. Variation of C_ℓ with β
Fig. 6 Concluded

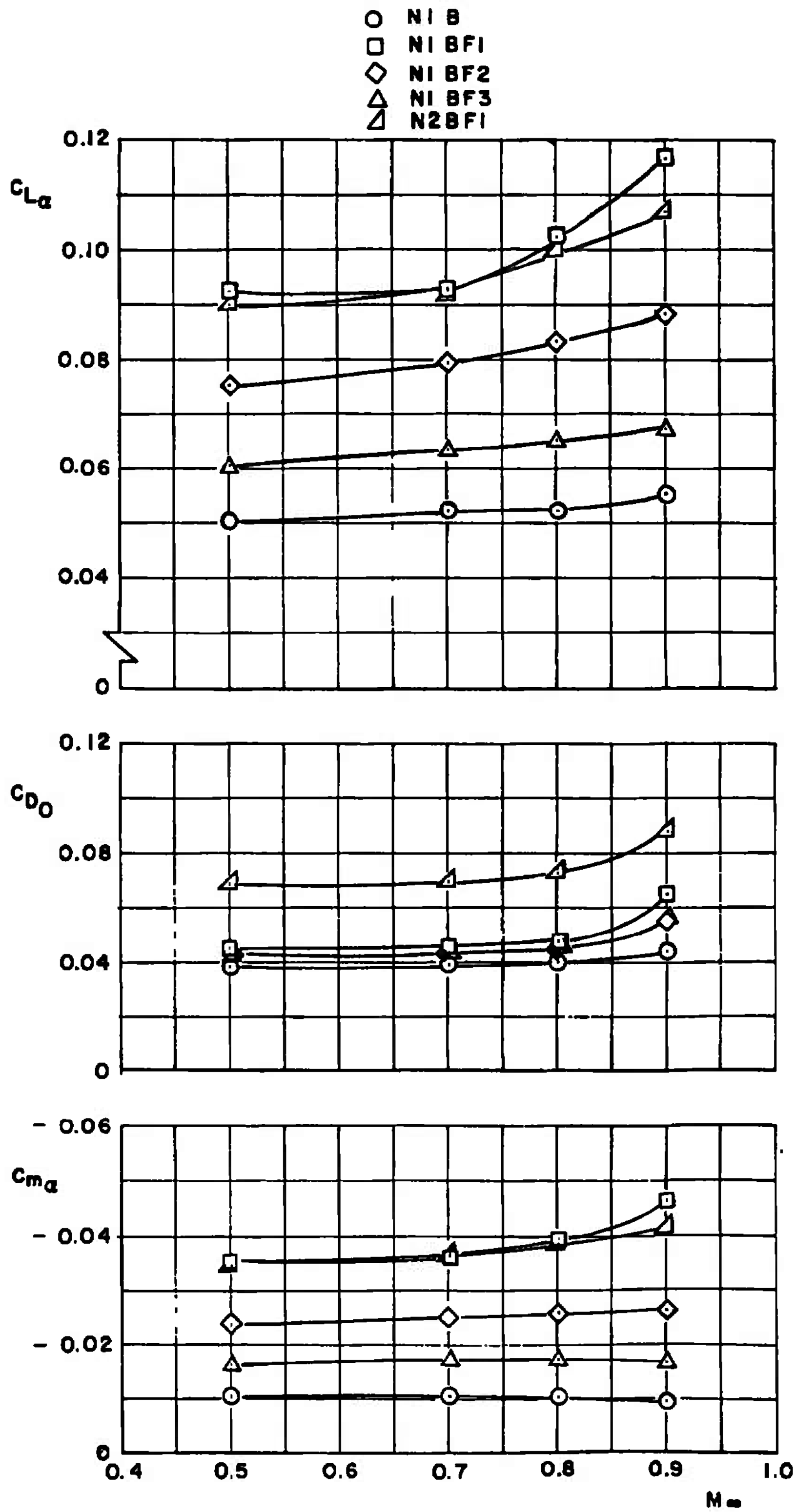


Fig. 7 Effect of Wing-Tip Fins and Nose Shape on Pitch Derivatives and Zero-Lift Drag Coefficient

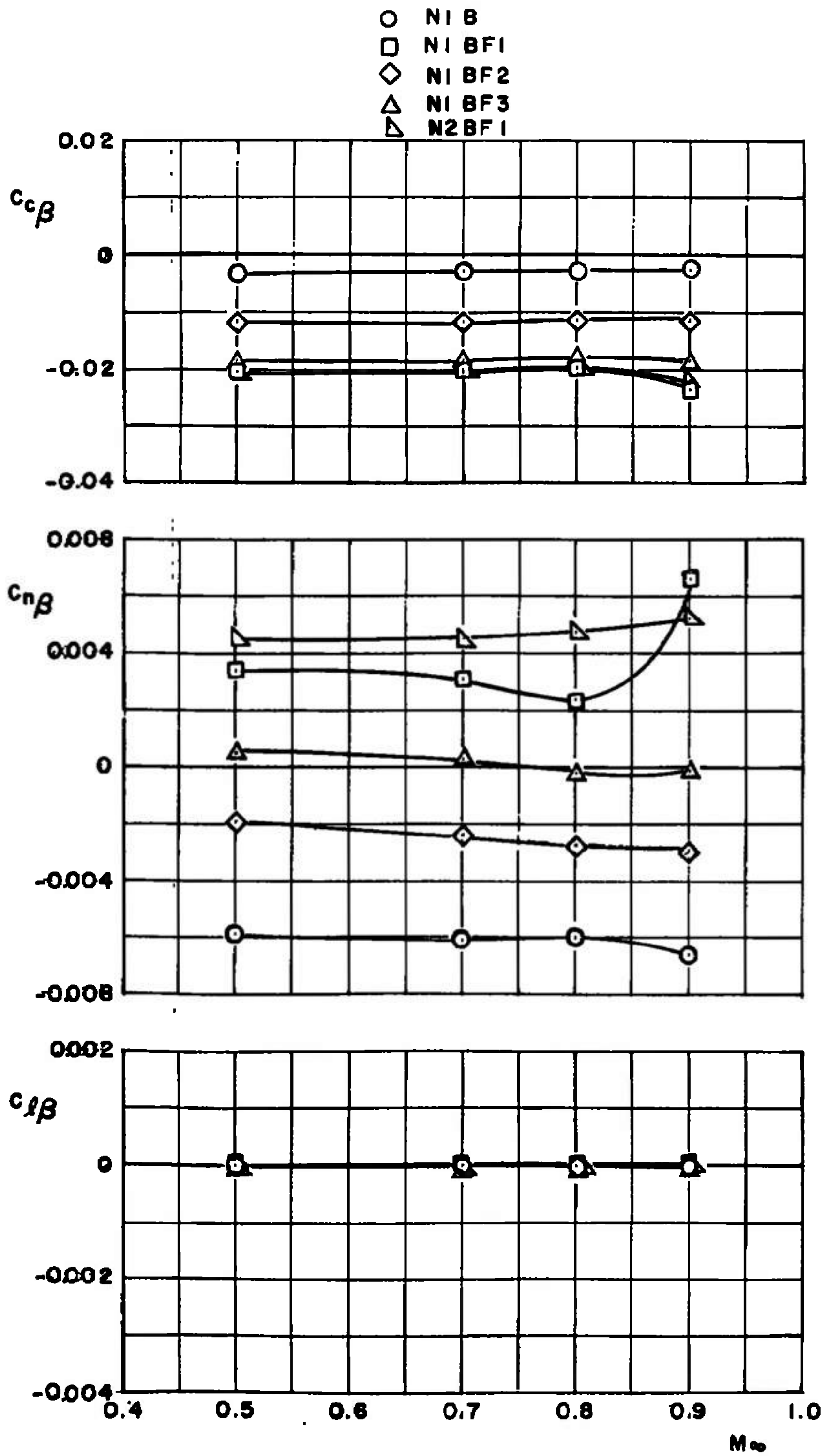


Fig. 8 Effect of Wing-Tip Fins and Nose Shape on Sideslip Derivatives (α = 0 deg)

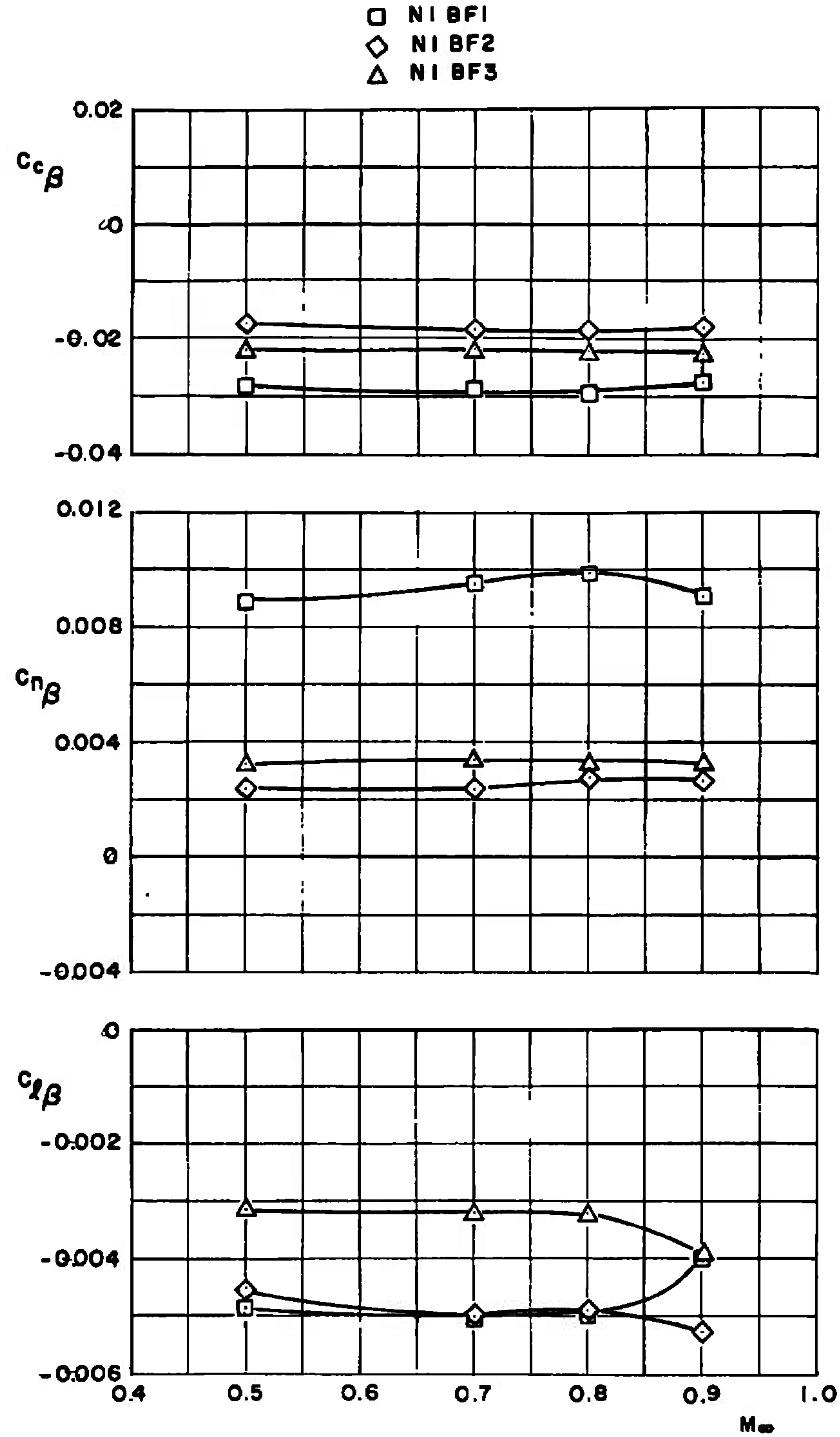


Fig. 9 Effect of Wing-Tip Fins on Sideslip Derivatives for $\alpha \approx 5$ deg

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Aerodynamic stability and drag coefficients were obtained for five configurations of a 0.166-scale tow target at Mach numbers from 0.5 to 0.90. The primary configuration variables were tip fin size and fin cant angle. Effects of a blunted ogive nose as compared to an inlet shape nose were also investigated.

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subsonic flow						

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